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IT'S IN THE BAG: SUBMARINE PLASTIC WASTE MANAGEMENT

ABSTRACT

The National Defense Authorization Act for fiscal year 1994 prohibits the discharge of plastic waste from U.S. Navy submarines after December 31, 2008. This requires the Navy submarine community to develop an effective method for handling and storing plastic waste aboard for eventual return to port. Paramount objectives include volume reduction, sanitary packaging of the waste, and locating suitable storage spaces on each submarine class without adversely impacting operational readiness or quality-of-life. Carderock Division of the Naval Surface Warfare Center conducted a review of all potential plastic waste processing options. The Naval Sea Systems Command set a priority to develop a method that would have the least impact on the submarine and its crew. The submarine trash compactor unit and Navy odor barrier bags were selected for the initial detailed investigation. The original concept was that plastic waste would be compacted into trash disposal unit cans to achieve volume reduction and the full can would be heat sealed into an odor barrier bag to provide sanitary storage. The submarine compactor was found to be very effective at reducing the volume of plastic waste, but laboratory testing showed that the odor barrier bags were not strong enough to contain the heavy and sharp edged trash disposal unit cans. Stronger barrier films were obtained

from industry and evaluated but none were one-hundred percent successful. A process was developed whereby plastic waste was compacted directly into high strength odor barrier bags called "submarine plastic waste containment bags." This simple process proved to be one-hundred percent effective in the laboratory. Potential storage locations for compacted plastic waste have been identified aboard the *Los Angeles* (SSN 688), *Ohio* (SSBN 726), and *Seawolf* (SSN 21) Classes. The *Virginia* (SSN 774) Class is the first Class of submarines that has been designed with a storage room for retention of plastic waste. A modification to the outboard section of the Wardroom Pantry is required to install a plastic waste storage locker aboard the *Los Angeles* Class. On the *Ohio* Class, the first emptied dry provision stowage module will be utilized and for the *Seawolf* Class the Dry Provision Locker was identified. Potential ventilation issues still exist with the latter two classes. Plastic Waste Management Demonstrations will be conducted on each submarine class to evaluate the suitability and effectiveness of the proposed plastic waste management solutions. The first demonstrations will be conducted on USS *Montpelier* (SSN 765) and USS *Tucson* (SSN 770) in fiscal year 1999.

INTRODUCTION

Submarine solid waste management has traditionally revolved around minimizing the waste that is brought onboard. The solid waste produced is compacted into trash disposal unit cans, weighted to ensure negative buoyancy, and discharged overboard. However, like the surface Navy, which used to throw all its solid waste over the side, new environmental regulations are restricting what and where material can be discharged. Recent amendments to the Act to Prevent Pollution from Ships (APPS) prohibit submarines from discharging plastic waste. This paper describes the submarine community's approach to complying with this law and the NAVSEA research and development program developed to enable the safe and sanitary retention of plastic waste.

BACKGROUND

Until the mid 1990s, the only restrictions on submarine solid waste discharge at-sea were self imposed due to operational or mission specific requirements. Traditional solid waste management consists of four main components: minimization, collection, disposal/treatment, and storage. Due to space limitations, submarines have, out of necessity, taken great steps to reduce the amount of solid waste that is brought onboard. Unnecessary packaging is removed pier side to minimize the amount of solid waste that must be managed at-sea. Traditionally, solid waste that is generated onboard is collected without separation.

All submarines built after 1950 have been equipped with a unique waste disposal system consisting of a Trash Compactor Unit (TCU) and a Trash Disposal Unit (TDU). The TCU is used to compact most solid waste into cylindrical metal cans (formed onboard from flat sheet metal using a can roller). The filled cylinders are then weighted for negative buoyancy and discharged through the TDU. Food waste is processed through a garbage grinder or packaged in plastic mesh “wet bags,” weighted for negative buoyancy,

and discharged through the TDU with the filled metal TDU cans. The TDU is designed to allow discharge of solid waste while the submarine is submerged. The major components of the TDU are a hydraulically operated muzzle ball valve, the operating shaft or TDU tube, and a breech door. The breech door is opened to allow the TDU tube to be filled with negatively buoyant TDU cans and wet bags. After closing the breech door, the TDU tube is flooded, the muzzle ball valve is opened to the sea, and the solid waste is flushed out of the submarine using seawater from the trim and drain header. This simple but effective system has been, and will continue to be, a crucial asset in the management of solid waste on submarines.

Current submarine solid waste management is governed by the Standard Submarine Organization and Regulations Manual (SSORM). Plastic waste management is governed by the 3/20 Day Rule, as described in the SSORM. This rule requires that plastic waste be separated from all other solid waste generated onboard and that the last three days of food contaminated and the last twenty days of non-food contaminated plastic waste generated prior to coming into a port be retained onboard. Plastic generated before these periods may be discharged beyond fifty nautical miles from shore. All other non-plastic solid waste is compacted into TDU cans and discharged overboard. Discharge of non-plastic solid waste must occur greater than twenty-five nautical miles from shore unless the submarine is in water one thousand fathoms or deeper in which case discharge is authorized as close as twelve nautical miles from shore. Food waste is packaged into plastic mesh wet bags and discharged through the TDU to the same restrictions as TDU cans. Some submarines have garbage grinders, which are used to process soft food waste into a slurry that is sent to a sanitary tank for eventual discharge.

If retained plastic waste compromises the safety or health of the crew, the Commanding Officer is authorized to discharge the waste, provided it is negatively buoyant, when greater than fifty nautical miles from shore.

LEGISLATION AND LAWS

The 1994 National Defense Authorization Act (NDAA) amended the Act to Prevent Pollution from Ships (APPS). APPS imposed the provisions of Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) on U.S. Navy ships. The 1994 NDAA extended the compliance deadline for submarines to December 31, 2008. Pertinent MARPOL Annex V provisions include a discharge ban on plastic waste worldwide and on solid waste in MARPOL "Special Areas" that are in effect. There are eight MARPOL Special Areas including the Mediterranean Sea, North Sea, Baltic Sea, Persian Gulf, Red Sea, Gulf of Mexico and Greater Caribbean Region, and the Antarctic Sea south of 60 degrees South Latitude. Currently, only the North Sea, Baltic Sea and Antarctic Sea are in effect. The other areas will be in effect when sufficient shoreside disposal facilities exist in their respective regions.

The 1994 NDAA also required the Navy to report to the Congress on their plan for compliance with APPS. The Navy's report [U.S. Department of the Navy December 1997] discussed the difficulty in meeting all the requirements, listed several options, and

detailed their preferred approach for compliance with APPS. The Navy's preferred approach detailed four waste treatment pathways: (1) use the TCU to compact all non-plastic solid waste for discharge through the TDU, (2) use garbage grinders to process all soft food waste for discharge through the sanitary system, (3) use non-plastic (i.e. cloth) wet bags for discharging non-grindable food waste through the TDU, (4) and retain all plastic waste onboard. A schematic of this approach is shown in Figure 1. The report was supported by an environmental assessment (EA) prepared by TAMS Associates regarding the discharge of non-plastic solid waste in TDU cans into MARPOL Special Areas. The EA resulted in a Finding of No Significant Impact. Congress agreed and made the Navy's preferred approach law with further amendments to APPS in the 1999 NDAA.

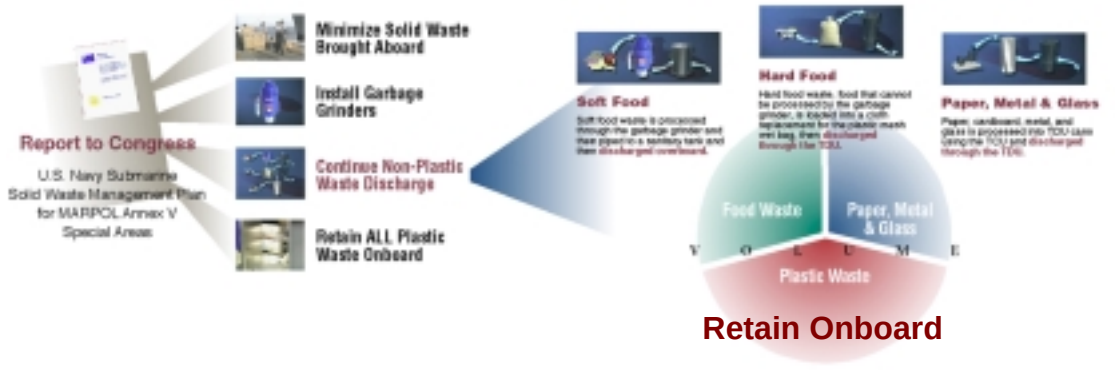

Figure 1
U.S. Navy's Preferred Submarine Solid Waste Management Approach

The Navy now has approximately ten years to implement the preferred approach aboard every submarine in the Fleet. All submarines have TCUs and TDUs. Garbage grinders have been proven for many years on the *Ohio* Class and SHIPALT 4102K has been developed to outfit the *Los Angeles* Class with them. NAVSEA, working with the Naval Inventory Control Point (NAVICP), has developed cloth wet bags. However, while several potential ideas were proposed, no one had determined the best way to retain the plastic waste onboard deployed submarines.

PLASTIC WASTE MANAGEMENT CHALLENGE

Managing plastic waste at sea poses unique challenges for the Navy especially on submarines. Operational requirements of submarines are extremely stringent and include aspects such as acoustics, endurance and self-sufficiency, atmospheric control, space and weight, and damage control. [U.S. Department of the Navy December 1997] Sanitation is always a concern when managing plastic waste. The closed atmosphere of a submarine heightens this concern and elevates health and safety to a top priority. The severe limitation of available storage space and restrictions of adding additional weight to the submarine restrain management options. Damage control issues such as reduction of the

risk of fire are paramount. Operational impacts, the effect on quality-of-life, and effects on overall mission readiness must be evaluated and minimized or eliminated.

The successful retention of plastic waste onboard submarines is contingent on overcoming three major challenges: (1) the volume of plastic waste to be stored must be reduced, (2) the waste must be packaged to eliminate odors, and (3) acceptable storage locations for the waste must be identified. Plastic waste is a very low density material. A typical bag of uncompacted plastic waste has a density of only 1.33 lb/ft^3. Seawater by comparison, has a density of approximately sixty four lb/ft^3. The low density of unprocessed plastic means that it will occupy a large amount of storage space. Further compounding the problem is the fact that approximately fifty percent of the plastic waste will be food contaminated and start to have a foul odor within three days. Obviously, to minimize the impact of storing plastic waste, a process will have to be employed that greatly reduces the volume of the waste and renders it odor free.

Storage of the plastic waste, depending on submarine class, may present as much of a challenge as developing a suitable packaging process. Submarines, by design, do not have any excess space. They are designed as extremely compact packages that maximize the use of their volume with ship and weapons systems. The *Los Angeles* Class actually stores dry provisions and canned goods in the walkways and on the deck of berthing spaces. There literally is no space to properly store anything extra on this class. The *Ohio* and *Seawolf* Classes are also space constrained, although not as severely as the *Los Angeles* Class.

Plastic waste generation rates are well documented on surface ships. Carderock Division, Naval Surface Warfare Center (CDNSWC) in the late 1980s and early 1990s conducted eight studies. The results of this work were statistically analyzed and resulted in a Navy surface ship design plastic waste generation rate of 0.20 lb/man/day. Only two submarines were surveyed during that timeframe and neither study collected data from the entire submarine. In 1994 Newport News Shipbuilding (NNS) used the data from these two submarine surveys, the surface ship data, and Fleet input to develop a plastic waste generation rate of 0.22 lb/man/day for submarines**.** While this number is scientifically credible given the data analyzed, it is difficult to believe that submarines generate more plastic waste per capita than surface ships given their mission and known solid waste management practices that rely heavily on the minimization of packaging. This generation rate value has been used by CDNSWC researchers to determine waste generation and the corresponding required storage volume, but it is believed to be a conservative figure.

Data and anecdotal information collected by the Fleet, primarily from COMSUBPAC in 1996, show much lower overall plastic waste generation rates and a trend of decreasing generation rate with mission duration. This information supports the belief that the NNS derived generation rate of 0.22 lb/man/day is conservative.

However, using the figure of 0.22 lb/man/day, a *Los Angeles* Class Submarine, having a crew size of 130 men will produce approximately thirty pounds of waste plastic a day or

858 ft^3 in a forty-five day mission. This volume of plastic would more than fill the entire crew mess area and create an unacceptable sanitation and odor problem.

OPERATIONAL AND DESIGN CONSTRAINTS

Any proposed plastic waste management solution must be compatible with unique submarine operational and design constraints. Submarines are extremely space constrained and operate at greater pitch and roll angles than surface ships but most importantly they operate submerged, requiring an atmospheric control system and extremely quiet equipment to reduce their noise signature. The normal design and ship integration considerations (i.e. weight, power demand, services required, etc.) also apply. The main drivers for any submarine solution, however, are that it has to be quiet, compatible with the atmospheric control system and take up little or no additional space. With these prime considerations in mind, initial goals were set and an investigation into the range of potential plastic processing solutions was begun in 1997. The initial thoughts on potential solutions were that they be no larger than the existing TCU, produce little or no fumes, and be as quiet or quieter than the garbage grinder or TCU/TDU.

TECHNOLOGY INVESTIGATION

A brainstorming session of CDNSWC engineers and contractors identified seventeen potential processes for treating (i.e. cleaning or sanitizing) or reducing the volume of plastic waste onboard submarines. These processes were divided into high technology and low technology depending on whether development of the process was required or if it already existed and could be utilized immediately without modification. The research and development program strategy established by NAVSEA was to first investigate low technology solutions and only proceed to the high technology solutions if necessary. The potential processes identified are shown in Table 1.

Low Technology Solutions	High Technology Solutions
Plastic Bag and Store	Freeze Drying
Wash, Plastic Bag and Store	Flash Freezing
Store in #25 Cans	Microwave Treatment
Navy Odor Barrier Bags	Irradiation
Trash Compactor Unit (TCU)	Extrusion Processing
Navy Plastic Waste Processor	Encapsulation
Submarine Oven	TCU with Heaters
Navy Solid Waste Shredder	Chemical Disinfection
	Chemical Treatment

Table 1
Technologies Identified as Potential Processing Solution Options

The low technology processing options were compared against the known submarine design constraints to down select processes for investigation. Most processes were easily

dismissed as not being practical or not meeting design constraints. The Navy Plastic Waste Processor (PWP) is the solution on surface ships but it is large, by submarine standards, and can produce fumes. The Navy Solid Waste Shredder is also large and does not maximize volume reduction (maximum of four to one volume reduction) to minimize storage space. Packaging plastic waste in plain plastic bags and/or #25 cans does not achieve any significant volume reduction nor does it provide an effective odor barrier. It would also not be desirable to process (i.e. melt) plastic waste in the submarine's oven. It became a simple deduction to identify the combination of the existing submarine TCU and Navy odor barrier bags (OBBs) as the obvious candidates for further investigation. The TCU would be used to compact the plastic waste into TDU cans providing volume reduction and the TDU cans would be bagged and heat-sealed in OBBs to achieve the required sanitation.

Evaluation of the TCU

An *Ohio* and *Los Angeles* Class TCU were installed in the laboratory at CDNSWC to determine their effectiveness at compacting plastic waste. The two compactors are similar, each drawing hydraulic power from the submarine to operate their rams, but the *Ohio* Class TCU has a larger hydraulic cylinder than the *Los Angeles* Class TCU that results in it having approximately five times the compaction force. This significant difference in compaction force required that both TCUs be evaluated. The *Seawolf* and *Virginia* Classes are being outfitted with the same TCU as the *Ohio* Class.

A test protocol was established that evaluated each compactor's ability to reduce the volume of various plastic waste streams including hard and soft plastic and simulated food contaminated plastic (using water). Both compactors performed well, processing approximately 150 lb of plastic waste per hour and producing average compaction densities of thirty-six and twenty-eight lb/ft^3 for the *Ohio* and *Los Angeles* Class TCUs, respectively. These achieved compaction densities are impressive and represent respective volume reductions of twenty-seven and twenty-one to one. Both compaction density and volume reduction were highly dependent on the operator compacting as much plastic waste as could be reasonably placed in the TDU can. The laboratory test results demonstrated that the TCU was quite capable of reducing the volume of plastic waste.

The TDU can has an approximate volume of 0.9 ft^3. Using this volume and the average achieved compaction densities, it was determined that approximately thirty-two pounds of plastic could be compacted into the TDU can by an *Ohio* Class TCU but only twenty-five pounds by a *Los Angeles* Class TCU. The effect of this on TDU can generation over various mission durations is illustrated in Table 2.

Mission Duration (Days)	Number of TDU Cans Generated		
	Ohio Class (150 man crew)	*Los Angeles* Class (130 man crew)	*Seawolf* Class (130 man crew)
	SSBN 726 TCU	SSN 688 TCU	SSBN 726 TCU
1	2	1	1
5	6	6	4
15	16	17	13
30	31	34	26
45	47	51	40

Table 2
Number of TDU Cans of Compacted Plastic Produced by
Submarine Class Over Various Mission Durations

Required Storage Space

TDU cans are cylinders approximately twenty-three inches long with an approximate nine inch diameter. They are perforated, which allows odor and liquids to escape, thus the need for an OBB. The required storage volume for a TDU can is greater than the volume of the can itself because of the can's circular profile. It requires a rectangular space of nine inches by nine inches by twenty-three inches (or 1.08 ft^3) to store a single TDU can. This equates to approximately fifty-six ft^3 on a *Los Angeles* Class Submarine during a forty-five day mission. While this volume represents a significant reduction from the unprocessed plastic, it is still a considerable amount of space on this class. Until recently, no existing submarine (or ship for that matter) was designed to store plastic waste. The *Virginia* (SSN 774) Class is the first class to include a storage area for plastic waste retention. It has an eighty-five ft^3 plastic waste storage area next to the TDU room. For the existing submarine classes the planning yards were brought in to find suitable storage areas. NNS was contracted to find suitable storage sites on the *Los Angeles* and *Seawolf* Classes for the TDU cans of plastic and the Electric Boat Division of General Dynamics (EB) was contracted to perform a similar survey on the *Ohio* Class. While this work was underway, CDNSWC began testing the OBBs as overwraps on the TDU cans.

OBB Testing

The Navy OBB was developed in 1991 to allow the odor free storage of food contaminated plastic waste aboard surface ships. The bags are five mil thick and employ layers of ethylene vinyl alcohol (EVOH) for a gas barrier, nylon for strength, and linear low density polyethylene for heat sealability. The bags were an unqualified success and are now used in consort with the PWP to bag the disks produced and on small ships that did not receive PWPs. The Navy OBBs were a natural potential solution to provide a moisture and vapor barrier around the TDU cans of compacted plastic. They had never been used in this application, however, and it was suspected that they may not be strong enough to contain the heavy and sharp edged TDU cans.

Laboratory testing began in 1997 and it was immediately apparent that the OBB by itself was not able to hold the TDU cans without puncturing or tearing. One hundred percent of the TDU cans overwrapped with OBBs punctured during this first round of testing. Several approaches to cushion the TDU cans were tried including duct taping the sharp edges, putting the TDU can inside a cardboard tube, and wrapping the TDU can with either a plastic bag or a wet strength paper bag. Double bagging of the TDU cans with OBBs was also tried. While all these methods improved the success rate, none could achieve one-hundred percent success. In fact, the most effective overwrap method was only successful sixty percent of the time. A better overwrap, stronger OBB, or both were needed for this application.

Numerous plastic film manufacturers were contacted to identify overwraps and stronger OBBs. Suitable candidates were obtained and brought into the laboratory for testing. The Navy also worked with DUPONT, Inc. to develop a stronger film for odor barrier bags. DUPONT, Inc.'s recommendation consisted of a coextruded barrier film laminated to woven polyethylene. Most products tested performed better than the Navy OBB but none was one-hundred percent effective (with or without overwraps). Two candidates (of nine) had a ninety-four percent success rate when used with a wet strength paper bag overwrap. It had become apparent that this application was too severe for a plastic film to survive. The TDU can was the real culprit; eliminating it would likely solve the puncturing problem.

Development of the Submarine Plastic Waste Containment Bag Process

Means to compact directly into the OBB were explored next with several metal sleeves developed to hold various OBBs in the TCU while plastic was compacted into them. These sleeves worked well but removing the full OBB was very difficult; it basically had to be shoved axially out of the sleeve with tremendous effort. A sleeve that could be easily opened after the plastic had been compacted into the OBB was needed. The TDU can fit this description perfectly. The very first test showed its efficiency and a variety of TDU can sized OBBs having various compositions were obtained and tested. A 10 mil thick product consisting of linear low density polyethylene, nylon, and EVOH emerged as the most effective OBB and was renamed the submarine plastic waste containment bag (SPWCB). The procedure used to compact the plastic waste into the SPWCB was refined and is shown in Figure 2.

The process to fill a SPWCB, begins with an empty SPWCB that is placed inside a rolled and formed TDU can. The TDU can has had the base and lid removed and is formed with the longitudinal tabs folded outward. The open end of the bag is rolled over the outside of the TDU can forming a cuff between ten and twelve inches long. The lined TDU can is then placed in the TCU and plastic is compacted into it until full. The TDU can is then removed and a plastic wire tie is used to tie off the SPWCB. The TDU can is then removed by unfolding the tabs on its longitudinal seam (which allows the can to open). The same TDU can, once reformed, may be used multiple times for compacting plastic into additional SPWCBs or used for non-plastic waste and discharged. The tied

off bag is then placed in another SPWCB which is heat-sealed shut with a commercial heat sealer and stored. The inner bag maintains the volume reduction but is typically ripped slightly during compaction. The outer bag provides an effective odor barrier. Figure 3 compares a filled SPWCB and a bagged TDU can of compacted plastic.

Figure 2
Submarine Plastic Waste Containment Bag Process

Figure 3
Comparison of SPWCB and an Odor Barrier Bagged TDU Can of Plastic Waste

STORAGE SPACE INVESTIGATION

NNS and EB were contracted to investigate potential plastic waste storage locations. Each contractor was given basic guidance to look for a storage location that could hold a large amount of compacted plastic waste, was close to the trash room to reduce handling, and could have a dual purpose as a dry provisions storage area prior to use for plastic waste stowage. Ideally the space would be well ventilated and not require modification to the submarine.

NNS surveyed sixteen *Los Angeles* Class submarines and interviewed numerous crewmembers in assessing suitable storage locations for this class. Identifying an acceptable plastic waste storage location on the *Los Angeles* Class posed the greatest challenge. NNS identified several potential locations but relocation of the equipment, materials, or function currently occupying the locations caused cascading impacts to the submarine. Initially constrained, the investigation was expanded to include the entire submarine. Several areas were assessed as potential storage locations, including the chosen site, which requires modification. That area was the outboard section of the Wardroom Pantry, shown in Figure 4.

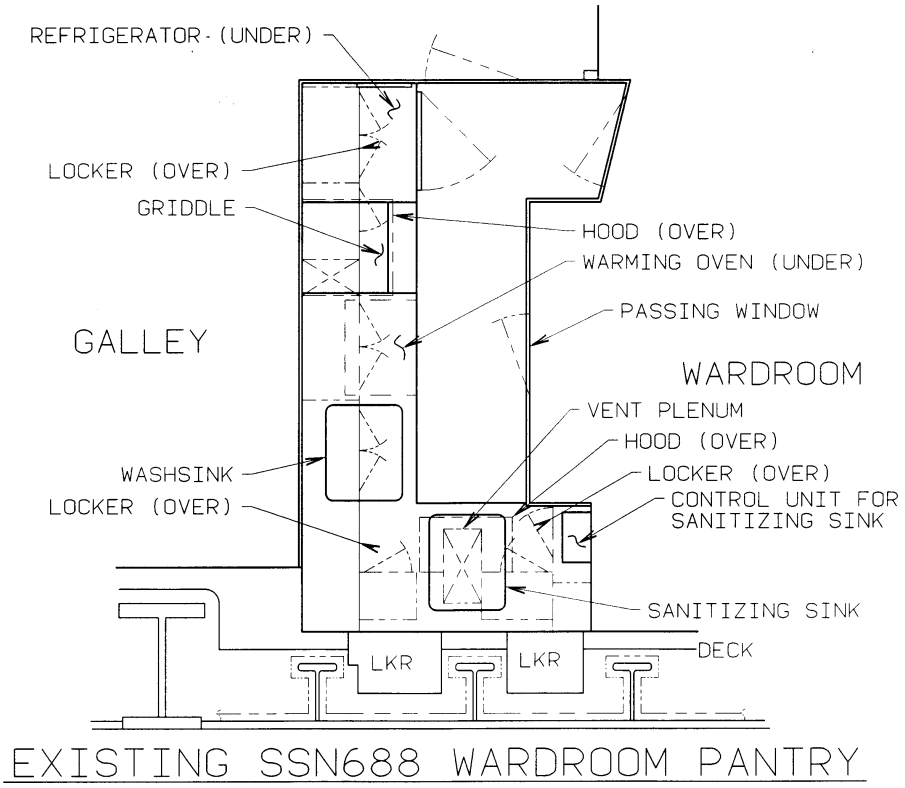

Figure 4
Plan View of the Wardroom Pantry

The outboard section of the Wardroom Pantry contains a sanitizing sink that is seldom used by most submarines surveyed. The NNS surveys found that the majority of submarines used the sanitizing sink and dishwasher in the scullery, leaving the Wardroom Pantry sanitizing sink a candidate for possible removal and conversion of the outboard area to a storage locker. NNS developed two storage locker designs. One made use of the entire outboard area and could accommodate thirty-two TDU cans; the other only used the space under the existing countertop. The latter option required a much simpler modification but could only hold approximately sixteen TDU cans of compacted plastic. Mock-ups of each design were fabricated and assessed in the laboratory and are shown as Figures 5 and 6, respectively.

Figure 5
Mock Up of the Full Size Outboard Wardroom Pantry Plastic Waste Storage Locker

Testing of the mock ups confirmed the projected capacity numbers with both TDU cans and SPWCBs. The tests also showed that tie down straps would not be required for the SPWCBs as they were not prone to rolling and clanging against each other during extreme submarine movement like the TDU cans. Testing did not reveal, however, which storage locker would be more useful onboard the *Los Angeles* Class. The full size locker held more plastic waste and had improved access (due to its larger door) but even this locker, which took up much more space, only held approximately sixty-two percent of the SPWCBs expected to be generated in a forty-five day mission (based on the conservative plastic generation rate of 0.22 lb/man/day). Fleet input was necessary to determine which locker to install.

Figure 6
Mock Up of the Outboard Wardroom Pantry Under the Counter
Plastic Waste Storage Locker

A dialog with COMSUBLANT and COMSUBPAC in 1998 highlighted the following Fleet concerns. While the majority of the *Los Angeles* Class Submarines surveyed were not using the Wardroom Pantry sanitizing sink, they did not want to lose the horizontal surface area provided by the countertop; they also believed that the true plastic waste generation rate was less than 0.22 lb/man/day. These two arguments formed the basis of the NAVSEA decision to proceed with the under the counter option despite its much smaller storage capacity. A section view of this locker is shown in Figure 6. This decision was endorsed by the Fleet and NNS was tasked with developing a TEMPALT Technical Data Package to install the under the counter option on a test submarine. CDNSWC orchestrated the test effort and developed all the necessary supporting documentation and purchased required consumables and equipment.

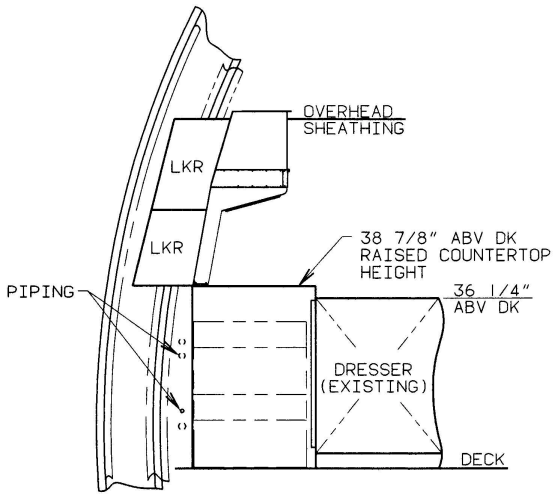

Figure 7
Section View of the Outboard Wardroom Pantry
Under the Counter Plastic Waste Storage Locker (Looking Aft)

This program has focused on the *Los Angeles* Class as the most difficult and challenging to find an acceptable storage solution. However, preliminary storage locations have been identified for both the *Ohio* and *Seawolf* Classes. The *Ohio* Class loads provisions in dry provision stowage modules approximately six feet tall, four feet wide, and four feet deep. The first stowage module to be emptied of its contents (which occurs in approximately nine days) will be used to store the SPWCBs produced for the entire mission as shown in Figure 7. A single storage module is capable of holding over 50 SPWCBs. Determining the need to ventilate the stowage module and how best to accomplish this is still an issue that is being studied. On the *Seawolf* Class the Dry Provision Locker, (11-039-001), on the first platform starboard at frame 39 has been identified as a possible storage location as well as Dry Provision Storeroom No. 1, (12-046-504). Additional time for this class at-sea will provide needed crew input to determine if these locations are truly feasible. Both of these locations are currently not equipped with direct ventilation. The requirement for ventilation is being studied.

Figure 8
Fifty SPWCBs Can be Stored in an *Ohio* Class Dry Provision Stowage Module

PLASTIC WASTE MANAGEMENT DEMONSTRATION PLANS

PLANS FOR THE *Los Angeles* CLASS

The Plastic Waste Management Demonstration is the at-sea evaluation of the SPWCB compaction process, plastic waste storage locations, and supporting documentation. It will determine the suitability of the selected solution for each submarine class with the *Los Angeles* Class being evaluated first. Two submarines (one each from COMSUBLANT and COMSUBPAC) were nominated to participate in the demonstration that will take place in fiscal year 1999. These are *USS Montpelier* (SSN 765) based in Norfolk, VA and *USS Tucson* (SSN 770) based in Pearl Harbor, HI.

The TEMPALT Technical Data Package was completed by NNS in 1998 and signed off by NAVSEA in December 1998 as TEMPALT 98117. NNS will conduct the installations on both *USS Montpelier* (SSN 765) and *USS Tucson* (SSN 770) during temporary availabilities early in 1999. SHIPALT 4102K, which installs a garbage grinder, will also be installed (or upgraded) on each submarine during their availability. *USS Tucson* (SSN 770) has TEMPALT 95187 garbage grinder but this installation will be modified to make it comply with the SHIPALT.

CDNSWC has developed a complete set of documentation to train and aid the crew in implementation of the Navy's preferred solid waste management option and in collecting the data necessary to support the plastic waste management demonstrations. These include "SSN 688 *Los Angeles* Class Plastic Waste Management Standard Operating Procedure", a training video entitled "Management of Plastic Waste Aboard U.S. Navy Submarines", and Quick Reference Cards that provide condensed instructions for compacting plastic into SPWCBs and using the heat sealer. The demonstration protocol is outlined in the "Plastic Waste Management Demonstration Test Plan" and the data collection requirements are stipulated in the "Plastic Waste Management Demonstration Test Booklet."

Data collection requirements have been reduced to the absolute minimum to minimize the burden to the crew. The submarine's Commanding Officer will provide a central point of contact (Supply Officer or Leading Mess Specialist recommended) to oversee the implementation of the plastic waste management program and data collection effort. The data collection requirements include marking the date and time produced and the storage location of each SPWCB on a label that is stuck to the bag, recording problems encountered and lessons learned in a log book, and filling out three survey forms following the deployment. The survey forms are intended to provide information to evaluate the SPWCB compaction procedure and plastic waste storage locker, cloth wet bags, and the garbage grinder.

The duration of the demonstrations are dependent upon the submarines' deployment schedule, but thirty to forty-five days would be optimum. CDNSWC personnel will meet each submarine when they return to homeport to view the offload of the plastic waste and collect additional data from the SPWCBs produced including measuring weight and assessing barrier integrity. This data will allow calculation of a plastic waste generation rate and assessment of the puncture resistance of the SPWCBs. CDNSWC personnel will then arrange for the transport of the SPWCBs to a recycling facility. This data combined with the information provided by each submarine will be used to determine the suitability and effectiveness of the proposed plastic waste management solution.

The approximate timeframe for the demonstrations aboard *USS Montpelier* (SSN 765) and *USS Tucson* (SSN 770) is third quarter fiscal year 1999. Following the demonstration and data analysis, a report on the results will be published in the fourth quarter of fiscal year 1999. If modifications to the plastic waste management solution are required, they will be developed and evaluated on another *Los Angeles* Class Submarine in fiscal year 2000.

PLANS FOR THE *Ohio* AND *Seawolf* CLASSES

EB is exploring several options for providing adequate ventilation to the food stowage module selected for storing SPWCBs aboard the *Ohio* Class. Once a method is selected, it will be evaluated in the laboratory at CDNSWC in fiscal year 1999. Information gained during the demonstration on the *Los Angeles* Class Submarines will be used to determine the need for the ventilation requirement. A demonstration aboard two *Ohio* Class Submarines will then be conducted in fiscal year 2000.

Operational data is required from *USS Seawolf* (SSN 21) to evaluate the suitability of the proposed storage spaces for SPWCBs on that class. If at-sea experience shows that the proposed storage locations (i.e. Dry Provision Locker and dry provision storeroom No. 1) are unacceptable, another option will have to be investigated and developed. Barring such an occurrence, a demonstration would be conducted on this class in fiscal year 2001.

CONCLUSION

The Navy research and development community has identified a simple and effective solution for processing and storing plastic waste onboard U.S. Navy submarines. The combination of submarine TCU, tougher odor barrier bags, and SPWCB compaction procedure minimizes the impact of storing plastic waste by significantly reducing the volume, eliminating odors, and maximizing storage capability. This solution has performed well in the laboratory and will be demonstrated aboard *Los Angeles, Ohio,* and *Seawolf* Class Submarines in the near future. Demonstrations will be conducted aboard two *Los Angeles* Class Submarines first, commencing in fiscal year 1999.

Onboard storage of the SPWCBs is still a critical issue especially for the *Los Angeles* Class. The plastic waste storage locker that will be installed on the demonstration submarines by TEMPALT will be evaluated by ship's crew during deployment. Fleet operational experience will determine adequacy of the stowage locker and the actual volume needed to store SPWCBs produced. This data and the suitability of the locker design will be provided during the demonstrations aboard USS *Montpelier* (SSN 765) and USS *Tucson* (SSN 770) in fiscal year 1999.

The final results on the effectiveness of the solution for the *Los Angeles* Class will be formally published by the end of fiscal year 1999. Demonstrations on the *Ohio* and *Seawolf* Classes will occur in fiscal year 2000 and 2001, respectively. This schedule will be accelerated where appropriate pending the outcome of the *Los Angeles* Class demonstration. Favorable results will allow the submarine community to easily implement their preferred solid waste management approach by the December 31, 2008 compliance deadline.

The beauty of the submarine plastic waste containment bag approach is its simplicity. This novel approach has the potential to revolutionize submarine plastic waste management without adverse impacts to operations, readiness, or quality of life. Simple

effective environmental compliance without high equipment costs - It's in the Bag: Submarine Plastic Waste Management.

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